CONSULTANT REPORT

LIGHTING EFFICIENCY TECHNOLOGY REPORT

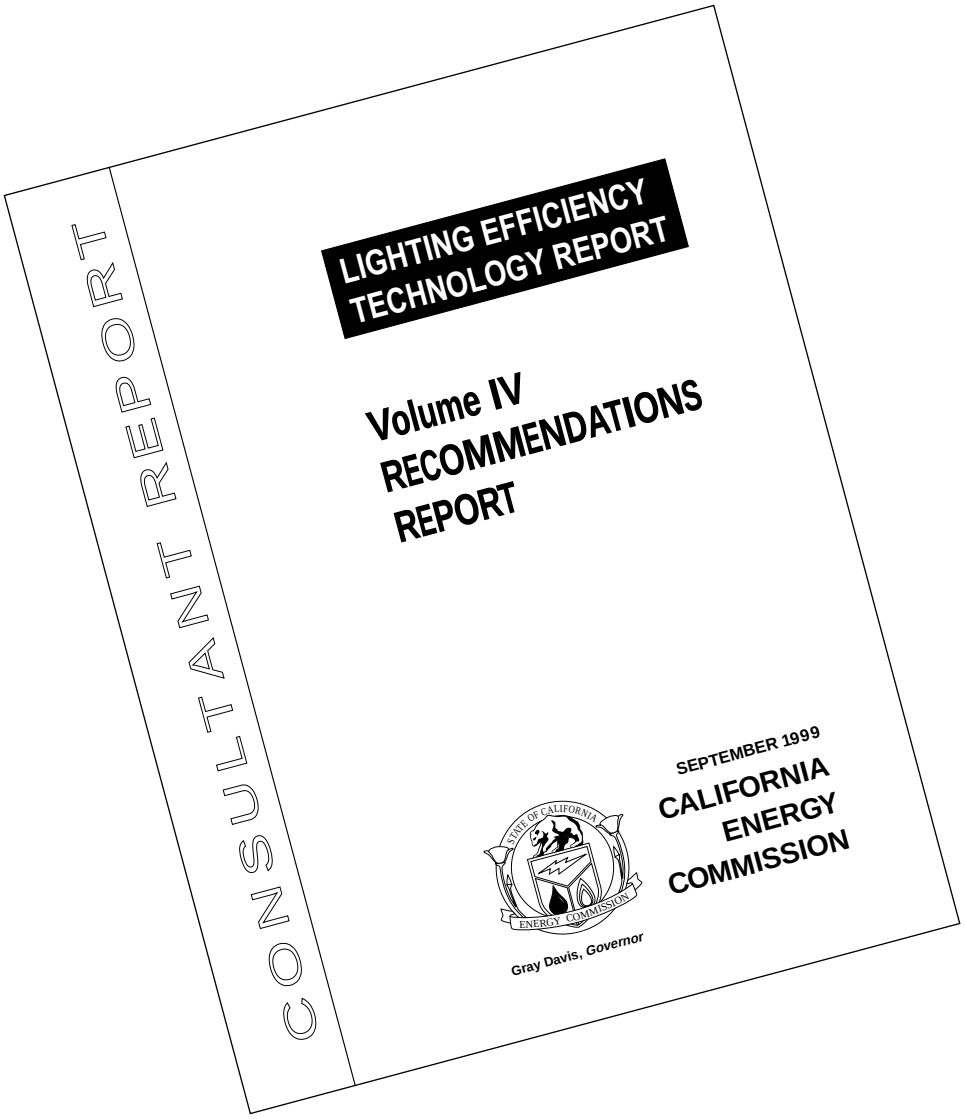
Volume IV RECOMMENDATIONS REPORT

SEPTEMBER 1999

CALIFORNIA ENERGY COMMISSION

Gray Davis, ***Governor***

P400-98-004VIV



C A L I F O R N I A E N E R G Y C O M M I S S I O N

Prepared for:

California Energy Commission

Prepared by:

Heschong Mahone Group
Fair Oaks, California
Contract No. 400-95-012

Maziar Shirakh, *Program Manager*
Michael S. Sloss, *Manager*

NONRESIDENTIAL BUILDINGS OFFICE

Scott Matthews, *Deputy Director*

ENERGY EFFICIENCY DIVISION

ACKNOWLEDGMENTS

This report is one of several being prepared under the *Lighting Technology Assessment Study* for the California Energy Commission. The study is being done as part of the Commission's response to the 1993 California Senate Bill SB 639 in which the legislature requested recommendations on ways to improve the efficiency of lighting in California.

The Commission's project manager for this study was initially Fred Berryman, and then John Sugar, with support from David Jones, and Ross Deter. The contractor team was led by the Heschong Mahone Group, Lisa Heschong and Douglas Mahone, Partners. Data analysis was provided by Ken Parris of B.E.A.R. The California Lighting Model was developed and run by Eley Associates, Charles Eley, Principal and Jeffery Luan, programmer. Additional lighting expertise was provided by James Benya and Ken Lim, and market research by Lisa Heschong of Heschong Mahone Group, Doug Oppedal of Benya Lighting Design and Merry Stubbins of SDV/ACCI.

This report has greatly benefited from additional resources provided by many people and organizations. Key in obtaining access to important databases have been Marian Brown of Southern California Edison, and David Lerman of Tacoma Public Utilities. Additional data was provided by members of Los Angeles Department of Water and Power, San Diego Gas and Electric, The City of Sacramento, CalTrans, and Lawrence Berkeley National Laboratory. Barbara Aktinson, Judy Jennings, and Frances Rubenstien of Lawrence Berkeley National Laboratory were particularly helpful in obtaining background information.

Members of the Lighting Efficiency Advisory Group (LEAGue) have provided information and support. Many retailers, manufacturers and professionals provided important background information for the market barriers study and participated in interviews. They were assured that their responses would remain anonymous. We greatly appreciate all their time and thoughtfulness in contributing to this project. The analysis and recommendations in this report, and any errors, however, are solely the responsibility of the authors.

There are four volumes to this Lighting Efficiency Technology Report:

Volume I: California Baseline Report

Volume II: Scenarios Report

Volume III: Market Barriers Report

Volume IV: Recommendations Report

TABLE OF CONTENTS

0. INTRODUCTION

The recommendations presented in this report are for actions that the California Energy Commission should take to promote greater lighting energy efficiency in the state. The recommendations are the result of a year long project assessing the current status of lighting energy use in the state and the most effective strategies for achieving long term energy savings.

This report is one of several being prepared under the *Lighting Technology Assessment Study* for the California Energy Commission. The study was done as part of the Commission's response to the 1993 California Senate Bill SB 639 in which the legislature requested recommendations on ways to improve the efficiency of lighting in California.

The project was performed in conjunction with meetings of the LEAGue, the Lighting Efficiency Advisory Group, convened by the Commission. The LEAGue members represent a variety of professional and industry groups from the lighting community. While the two efforts have been concurrent, and we have shared many discussions, the LEAGue has made its own set of recommendations to the Commission. The recommendations in this report are specifically the conclusions of the report authors.

For the sake of brevity, this report does not attempt to document every finding and statement upon which these recommendations are based. Rather it summarizes the findings from the project final report, where all sources, assumptions, references and methodology are documented. Please refer to the final project report for further detail not provided in the discussion of these recommendations.

Five major recommendations are presented, in order of priority, based on our assessment of their potential benefits and costs. These five recommendations are:

1. **Update the commercial lighting power density standards**
2. **Support development of an efficient a-lamp replacement**
3. **Adopt a three step approach to residential lighting efficiency**
4. **Support lighting education**
5. **Support research on lighting energy use**

The background and rationale for each recommendation is discussed, and then specific actions are recommended for the Commission to undertake in support of each recommendation.

1. UPDATE COMMERCIAL TITLE 24 LIGHTING STANDARDS

1.1.1 Background

Commercial lighting energy efficiency has consistently been shown to be one of the most effective means to reduce energy consumption in buildings. Utility program impact evaluations have demonstrated that, of all building efficiency options, lighting efficiency measures have the largest overall net impact on both energy savings and peak demand reductions. The energy savings are usually amplified by secondary effects in reducing building cooling loads. Lighting efficiency measures for new construction have been found to be especially persistent: once adopted, they tend to stay in place, and to continue saving energy for the life of the lighting system.

Revisions to the energy code have the permanent effect of raising the standard level of practice in the entire lighting community. Because of the rate of new construction and renovation in commercial buildings, a revision to building energy standards will affect the entire building stock within about 15 to 20 years.

California's Title 24 Building Energy Standards have been acknowledged as one of the major driving forces in improving the energy efficiency of the lighting industry. Fixture manufacturers across the country who were interviewed for this study uniformly acknowledged Title 24 as the primary driving force for increased production and marketing of efficient lighting technologies.

In the two decades since it was enacted, Title 24 has come to define the basic standard of practice for the California lighting industry. Our analysis shows that by 1992-4, on average, the existing commercial building stock had achieved better than 100% compliance with the lighting standards, exceeding Title 24 lighting power density requirements by a net of 5%. This is a major achievement.

Lighting professionals who interviewed for this study confirmed this finding by agreeing that their own lighting installations typically exceed Title 24 requirements. They all agreed that exceeding the Standard requirements by 10% is feasible and "easy." Indeed, new installations are frequently seen to exceed the requirements by 25% or more. At this point, the current Title 24 Standards could actually become an impediment to advances in the overall efficiency of commercial lighting by holding standard practice down.

Lighting Power Densities

The maximum lighting power density levels currently allowed by Title 24 were developed over a decade ago, based on technologies that were commercially

available in 1986. The efficiency of lighting products has advanced dramatically in the past decade. Efficient lighting products that were just being introduced on the market in 1986, such as T8 fluorescent lamps and electronic ballasts, or fixtures using compact fluorescent lamps, are now considered standard products throughout the state. The lighting industry infrastructure that supports the use of these products, from manufacturing through specification and distribution to installation, has also matured.

Our analysis shows an enormous potential for energy savings and demand reduction that could result by simply bringing the Title 24 lighting standards up-to-date based on those efficient technologies that were commercially available in 1996. A first step is to revise the standards based on using T8 lamps and electronic ballasts in all existing full size fluorescent applications, which can save about 2,800 gigawatthours per year. As a further step, the standards could be revised using the currently optimum cost-effective, efficient technologies in all commercial lighting systems, not just full size fluorescents. This approach can save an additional 60%. If such an upgrade of the Standards were implemented, it would result in over 1,000 megawatts in electricity demand reduction and 4,300 gigawatthours of energy savings per year for the state. This is equivalent to removing one nuclear power plant from production and saving California businesses about $350 million dollars per year.

It is possible to lower the overall lighting power density for the California commercial building stock by an average of 30% using only standard 1996 technologies, and without lowering the lighting levels in any spaces.

A national model lighting energy code has been under development in the ASHRAE/IESNA Standards 90.1 process which incorporates many of the features initiated earlier in Title 24. A revision to this national standard is currently underway, updating lighting standards. However, the current proposed revisions to the ASHRAE/IESNA lighting standards would have little impact in California, because our building stock is already very close to the proposed levels of efficiency. Indeed, efficiency levels might actually be worse than existing in some space types. Thus, adopting the proposed ASHRAE/IESNA standards would not gain much for California, and would nullify California's important leadership position in helping to move the lighting industry towards greater efficiency.

Controls

Both the Title 24 and ASHRAE/IES lighting standards include provisions for a variety of automatic lighting controls. It is generally believed that automatic controls should reduce lighting energy use significantly. However, this study could find no conclusive proof one way or the other. Many field studies looking

at “before and after” energy use comparisons for controls have shown a combination of both increased and decreased energy use within a building, or among a number of buildings. Those field studies have generally had very limited samples and limited purposes. There have been no broad-based, carefully controlled studies to date which assess the impact of lighting controls. Unfortunately, the datasets used for this study could not distinguish any causal effects for controls saving energy. Thus, we do not have sufficient information to make any firm statements about the energy saving impacts from the use of automatic controls.

In the energy analysis portion of this study, increased use of occupancy sensors was studied, using a set of conservative assumptions about reductions in net hours of operation. When this measure was applied to the existing building stock, it saved over 1,000 gigawatthours of energy per year. However, when the same measure was applied to a more efficient building stock, based on upgraded Title 24 requirements, the resulting energy savings from controls were reduced in magnitude by 60%. Thus, the impact of automatic controls is greatly lessened when the overall lighting system becomes more efficient. The appropriate cost/benefit balance between using more efficient systems and using lighting controls cannot be understood until there is better evidence on the overall performance of controls in the field.

Thus, any revisions to the controls aspect of the lighting standards should await better data on the actual impact of controls, per the recommendation for field studies on control impacts discussed later in this report.

1.1.2 Recommendation: Revise LPD Standards Based on Current Efficient Technologies

California should initiate a process to upgrade the lighting power densities required by Title 24 non-residential lighting standards based on commercially available and cost effective efficient lighting technologies for all applications. This would bring the Standards up to current practice levels and would continue to lead the lighting industry toward the goal of efficient lighting.

2. SUPPORT DEVELOPMENT OF EFFICIENT A-LAMP REPLACEMENT

2.1.1 Background

Our analysis shows great promise for an advanced incandescent lamp which could be a direct screw-in replacement for standard incandescent light bulbs. For example, a tungsten halogen infrared reflecting (HIR) lamp, used in both residential and commercial applications, has the potential to reduce demand and save as much energy per year as upgrading the Commercial Title 24 Lighting Standards, discussed above. Such a product could reduce statewide lighting demand on the order of 1,000 megawatts and save approximately 4,000 gigawatthours per year. This is a huge potential for energy savings.

There is a recognized need for an energy efficient, and economical, replacement for standard incandescent light bulbs. They are commonly referred to by their configuration as an “A-lamp,” or by their screw-in base as a “medium” or “Edison base” lamp, or as a General Lighting Service (GLS) lamp. Sold in supermarkets and hardware stores everywhere, they are very inexpensive, and available in a variety of options—a range of wattages and lumen output, soft white, long life, bug lights, etc. They are also highly standardized—so that almost any A-lamp product can be used in any fixture with a screw-in Edison base. They represent almost 90% of the residential and 20% of commercial installed lighting watts. The ideal replacement lamp would be significantly more efficient, last longer, and be just as convenient to purchase and use as the A-lamp.

While compact fluorescent lamps can be cost effective replacements for those incandescent lamps in applications with long hours of operation, CFLs also face a wide range of market barriers and operating characteristics that make them unsuitable or uneconomical for many applications. An advanced incandescent lamp could be manufactured with similar photometric properties as standard incandescent lamps, and could have the same operating characteristics, such as dimming capability, instant on, and lack of temperature sensitivity. If it can be marketed in a price range of $3 to $6 per lamp, it is also within the price range expected for products at consumer outlets such as grocery stores. Thus, it is more likely to be successful on the consumer market.

The HIR lamp is conceived as a direct screw-in replacement for existing standard incandescent lamps. In our analysis they are assumed conservatively to operate at 22 lumens per watt at smaller sizes, and 25 lumens per watt for larger sizes. A few halogen infrared reflecting products have been commercially available in parabolic reflecting configurations, or PAR HIR lamps, since about

1992. Prototypes of HIR A-lamps have been produced at Lawrence Berkeley National Lab. In 1995 one lamp manufacturer announced it would start marketing an HIR A-lamp, but then did not actually make it commercially available. Manufacturers hint that there may still be some subtle technical issues that remain to be resolved.

Low-e window glass followed a similar research and development path, and has since reached commercialization, saving consumers significant energy costs. Low-e glass uses a similar infrared reflecting coating technology as HIR lamps to improve energy performance. It was researched and demonstrated at the national laboratories. Manufacturers were initially reluctant to incorporate the necessary equipment into their manufacturing plants. But once one major window manufacturer adopted the technology, diffusion was very rapid among all the other window manufacturers. Today, low-e windows are available nationwide as a standard product. HIR technology for lamps has similar potential.

In addition to the infrared reflecting technology, there are other innovative technologies which may eventually be able to improve the efficiency of the incandescent lamp. A ceramic filament which can operate at high efficiency and with a long life has received some study. At this point, the infrared reflecting technology is the nearest to commercialization.

2.1.2 Recommendation: Support R&D of A-Lamp Replacement

An efficient replacement for the screw-in incandescent lamp has enormous energy saving potential. The development of an HIR A-lamp uses a very near-term technology, and seems poised on the verge of commercialization. Some targeted research to resolve performance optimization, manufacturing, or marketing issues may be necessary to take it the last step to commercialization. We recommend that the CEC identify key areas that will benefit from public support to move this promising technology forward. For example, technical specifications could be developed that embody the "drop-in" replacement product vision expressed above. Also, development of commercially produced prototype lamps may be an important next step.

2.1.3 Recommendation: Join in Procurement Efforts

Efforts to spur manufacturers to create such a lamp have recently revolved around procurement initiatives. The idea is to create a large enough market to make it worthwhile for a manufacturer to initiate production of an efficient A-lamp replacement.

On a national level, the Department of Defense, through its Defense General Supply Center, has issued a request for procurement, offering to purchase

millions of HIR units over three years. They have issued very ambitious specifications for this bulk purchase. Their target has been for a lamp which lasts at least 3,000 hours, and is at least 30% more efficient than current incandescent lamps. It is not specifically aimed at any one technology, i.e., it is "technology neutral.". Procurement prices were set based on the efficacy of the resulting lamp, starting at $3.00/unit for a 25 lumen/Watt lamp, and rising to $6.20 for a 70 lumen/Watt lamp.

The price point and efficacy level of the appropriate product remain controversial between the manufacturers and government agency. A necessary next step to encourage investment in the manufacturing capability for this technology may be identifying an even larger, more stable market or agreeing upon lower specifications for the procurement.

The International Energy Agency has also announced formation of a group of interested parties in Europe for a similar group purchase. Although technical specifications had not been finalized as of this writing, it would probably be similar to the US Department of Defense specifications.[1]

California could establish its own procurement effort to encourage manufacturers to market an HIR A-lamp replacement, or it could join in a larger buyers' group, such as one organized by the federal government. Both EPA and DOE are encouraging these efforts. State agencies responsible for managing large residential facilities such as dormitories or prisons, or any facilities with substantial inventories of incandescent lamps, are likely candidates to join in such a mass purchase of efficient lamps.

[1] Cooperative Procurement on Improved GLS Lamp, Nils Borg, IAEEL Newsletter, January 1996.

3. ADOPT A THREE STEP APPROACH FOR RESIDENTIAL LIGHTING EFFICIENCY

Residential lighting energy use has been shown to be significant: about 2/3 the size of commercial lighting energy use, and 8% of overall statewide electricity use. Residential installed lighting wattage is three times the commercial level, and residential lighting loads on electric utilities are equivalent to 83% of commercial lighting loads in the early evening peak demand period (6 PM).

Residential lighting remains vastly less efficient than commercial lighting, and has not benefited from the many recent improvements in lighting technology. Because of the scale of residential lighting energy use, and because of its inefficiency, there is significant potential to save energy and reduce utility demand with residential lighting efficiency measures.

Residential lighting has a very different market structure than commercial lighting. New construction standards have a much smaller, and slower impact on residential lighting than on commercial lighting. Residential lighting is driven by the diffuse consumer market, rather than more concentrated wholesale purchasing. Fixtures are most often selected for aesthetics, and lamps are most often purchased as a commodity, based on price and convenience. A large portion of residential lighting is portable, such as table and floor lamps, and moves with the homeowner. Retailing of energy efficient lighting products is constrained by the demands of the mass merchandising system. A large portion of residential fixtures are manufactured overseas, and sold at discount prices, creating a very competitive market where quality and performance are usually at a price disadvantage.

For all of these reasons, it has been difficult to develop an effective strategy to promote efficiency in the residential lighting market. To reach this complex market, the Commission should take a three step approach:

- Take advantage of the existing energy standards for new construction, and continue to insist upon a minimum level of efficient lighting permanently wired into new homes.
- Focus on overcoming market barriers to consumer adoption to efficient technologies, and on raising consumer awareness of lighting issues.
- Participate in labeling programs and gradually introduce new appliance standards for residential lighting that improve their safety and efficiency.

3.1 Residential Title 24 Lighting Standards

3.1.1 Background

New construction remains the most cost effective opportunity to integrate efficient lighting, which will steadily improve the overall efficiency of housing stock. California was the first state to adopt lighting measures into its residential energy standards. An efficient (i.e. fluorescent) lighting fixture is currently required in kitchen and bathrooms. The Title 24 requirement is very simply stated, requiring only a few lines of text.

As a result of this measure, fluorescent lighting very clearly increased in California homes. Our analysis shows that the percentage of fluorescent lighting installed in single family homes took a dramatic jump upwards after the Standards were instituted in 1978. That level appears to have remained steady since, and is higher than comparable homes surveyed in other states.

However, after an initial dip around 1978, the amount of incandescent lighting has also steadily risen. The average installed watts per home has increased by an average of 100 Watts per decade. Much of this is attributable to a steady increase in the size of homes, with a corresponding lack of improvement of the efficiency of lighting sources. Combined with the incessant increase in California's population, this growth in residential lighting energy use is clearly an unsustainable trend.

Our analysis suggests that simply achieving full compliance with the current Title 24 provisions would result in an additional 200 gigawatthours of energy savings per year, and would reduce the statewide installed residential wattage by 240 megawatts. Abandoning the lighting standards would result in a corresponding increase in energy use.

New information on the energy impacts of residential lighting, including this report, is just coming available and is starting to attract national attention. Whereas residential lighting measures have been ignored in other residential energy codes up to now, primarily because of lack of information, there is interest in finding appropriate ways to address lighting energy efficiency along with the standard building envelope and HVAC concerns. The Model Energy Code (MEC) and the Home Energy Rating System (HERS) are both potential organizations that may consider lighting efficiency measures in the future. They are likely to want to follow California's lead.

Kitchen Lighting

Title 24 requires that general kitchen lighting be fluorescent. The intention of this requirement was clearly to require efficient lighting for almost all kitchen lighting.

The language distinguishes between “general lighting” which must be fluorescent and “specific decorative effects”, which may be from incandescent sources. However, over the years the interpretation of “general lighting” has been liberalized to mean “some lighting,” and “specific decorative effects” has been taken as an excuse for as many other incandescent fixtures as can be installed.

Since there is no limit on the total amount or wattage of lighting provided, builders have often simply added more fixtures to the kitchen, increasing the overall lighting power density. This is often cited as a symptom of failure of the Title 24 provision. However, our analysis shows that homeowners tend to make more intensive use of fluorescent fixtures. Fluorescent fixtures in kitchens are operated for more hours per day on average than incandescent fixtures. Thus, a higher rate of installation does not necessarily mean a higher rate of use. Provision of a fluorescent fixture clearly gives the homeowner an option to choose a more efficient source.

Bathroom Lighting

Title 24’s requirement for fluorescent lighting in bathrooms has been one of its most controversial residential provisions. Home builders are especially unhappy about the requirement, complaining that it compromises the marketability of their homes. They complain that attractive and economical fluorescent bathroom fixtures that meet customer expectations for lighting quality are impossible to find. The survey of lighting retailers bore this out, with 75% of retailers surveyed reporting that they did not carry “decorative” bathroom fluorescent lighting as a standard item. (All of them did, however, carry “utility” bathroom fluorescent fixtures.) In the recent past, bathrooms have become less and less of a utilitarian feature of homes, and more and more of a luxury feature, demanding more decorative fixtures.

On the other hand, assertions that there was very low compliance with the Title 24 bathroom provisions were not confirmed in our study. California was found to have a higher proportion of fluorescent lighting in bathrooms than other states, and one third of all lighting (lumens) in bathrooms in new single family homes was found to be provided by fluorescent lighting. In our modest survey of contractors who do both remodels and new construction, 81% responded that they install fluorescent lighting in most bathrooms, which was actually higher than the rate reported for kitchens. 19% of the contractors reported that they only occasionally or rarely installed fluorescent bathroom lighting, and not one responded that they never do.

Fixture manufactures reported that they have found a significant market for residential fluorescent fixtures in California because of the Title 24 requirements. New technologies have enabled fluorescent fixtures to be indistinguishable from

incandescent fixtures in performance and light color. Blind tests with customers at utility education centers have found that people typically cannot distinguish between a table lamp using a high performance fluorescent vs. an incandescent lamp.

Residential fixtures using these technologies are just starting to appear on the market. A CFL fixture manufacturer reported that while five years ago they had no competitors in the California market, now they have a half dozen aggressive competitors. As a result, their CFL fixture prices have dropped by 30%. One California utility has just begun a buy-down program to encourage more retailers to sell and display dedicated CFL ceiling mounted fixtures. The participating high performance fixtures are selling at retail outlets for $10 to $20. A recent survey of fluorescent bathroom vanity fixtures identified about 15-20 residential and 30-40 commercial grade products on the market. Fixture manufacturers are counting on Title 24 to be a continuing force in driving the market for these fixtures. Thus, the problem of lack of selection of appropriate fixtures is being resolved as the market develops.

Bathrooms were found to consume almost 13% of residential lighting energy use, and 16% of installed watts. They have somewhat shorter hours of operation than the average residential use, which could argue that this is not the most cost effective location for fluorescent fixtures. On the other hand, the large energy use of bathroom fixtures due to their high wattage and the huge population of fixtures argue that this is an important market segment for efficient fixtures. It can make a significant contribution to energy savings and to the penetration of fluorescents in the residential sector.

While compliance with the bathroom lighting requirement may be imperfect, it is having an impact. Some home builders have been very vocal in expressing their dislike of the provision, but the evidence is that the majority of new bathrooms in the state have some fluorescent lighting, and that most contractors now accept the requirement. The provision was clearly ahead of its time when it was instituted, and has received a lot of criticism because of that. But the lamp and fixture market has gradually been catching up and is now within hailing distance of being able to meet the needs of contractors.

Outdoor Lighting

In order to achieve significant and cost effective energy savings, lighting efficiency programs should target either those lighting fixtures which operate for the longest hours, or those applications which have the greatest number of inefficient fixtures. Outdoor lighting meets both of these criteria.

Outdoor lighting constitutes 15% of residential lighting energy use, 12% of installed wattage and 13% of fixtures. The hours of operation for outdoor lighting is above the average for residential fixtures, averaging close to 3 hours per day.

Outdoor lighting is considered one of the primary "growth" areas in residential lighting. The amount of outdoor lighting installed statewide is expected to continue growing for the foreseeable future. Homeowners are eager to make improvements to their yards, extend the hours of use, and provide decorative and security lighting for their homes.

There are a number of simple, commercially available options for improving the efficiency of outdoor lighting. Our analysis suggests that implementing these efficiency options for outdoor lighting in residential new construction could save between 150 and 340 gigawatthours per year, and reduce installed lighting wattage by 130 to 240 megawatts.

A very simple approach to specifying efficient outdoor residential lighting has been developed for EPA's Energy Star labeling program. It basically requires that outdoor light fixtures above a minimum wattage either incorporate automatic controls to limit hours of operation, or use an efficient light source. This specification has been developed to support a product labeling program initiated by the EPA. The same specification could be incorporated into Title 24 as a requirement for outdoor lighting fixtures installed in new homes.

The controls specification requires that there be a combination of photo sensor and motion detector to reduce unnecessary hours of operation for incandescent fixtures. There is no outdoor lighting that is useful when the sun is up; photo sensor controls turn off lights in daylight. Motion detectors reduce hours of operation to just those times when the light is actually needed because someone is present. Motion detectors have the added benefit of enhancing the security aspect of night lighting by suddenly shining a light on intruders in an otherwise dark setting.

The efficiency specification states that the higher the wattage of the fixture, the more efficient should be the source that is used. For those outdoor applications which are left on for long hours, such as security night lighting, this approach is sensible and cost-effective.

Given that suitable fixtures and controls already exist to meet this spec, and that they are not applied inside the home, the market barriers to their use are very low. Three quarters of all retailers surveyed for this study already carry outdoor fixtures with integrated controls, and three quarters also carry fixtures that use dedicated compact fluorescent lamps. HID fixtures are, of course, already a well established product. The EPA is expecting fixtures carrying the Energy Star label

to appear on retail shelves in the summer of 1997. Thus, the market seems ready to support this recommendation.

Indoor Fixtures

Indoor fixtures hardwired to the wall or ceiling of a home are the most common residential fixture type. Ceiling and wall mounted fixtures together represent about 2/3 of residential lighting energy use.

As of yet, there are no specific initiatives for improving the efficiency of all indoor hardwired lighting fixtures. There are, however, existing requirements for providing lighting fixtures in homes.

The National Electric Code (NEC) requires that hardwired lighting fixtures connected to a wall switch be provided in most rooms of a house. A fixture is required in kitchens, bathrooms, hallways, stairways, utility rooms, garages, and at outdoor entrances and exits. Thus, the NEC provides a good definition of the minimum number of fixtures that must be provided in a residence. This list includes those fixtures with the longest hours of operation—kitchen, garage and utility room ceiling fixtures, and outdoor wall mounted fixtures—those fixtures which are often used for security or night lighting, such as bathrooms, hallways and stairways, and those fixtures already covered in Title 24, i.e. general lighting for kitchens and bathrooms. Thus, it provides a very convenient, comprehensive and simple way to define those fixtures which should be targeted for higher efficiency.

Efficiency standards could be adopted for these minimum fixtures, when and if the fixture market develops such that expanded efficiency standards would be cost effective in residential new construction.

An alternative approach, that needs more study, is to consider specifying maximum installed watts per square foot standards for various room types, similar to the commercial energy code. If a watts per square foot cap were placed on kitchen or bathroom lighting, more efficient fixtures would have a major market advantage, allowing higher light levels within the standards. Such an approach would be technology neutral. It would, however, require changes in compliance procedures for residential buildings. First, more information on existing levels of illumination and lighting power densities in homes should be analyzed.

3.1.2 Recommendation: Simplify Kitchen and Bathroom Compliance

The current Title 24 language is quite straight forward. Interpretations of the language have, however, multiplied. Allowing subtle interpretations and multiple substitutions complicates the compliance process enormously. Agreeing on one

simple interpretation will greatly assist the code officials who enforce the Standards and provide clear direction to the building community. The worry that some code officials allow competitors to get away with a fuzzier interpretation of the rules is more disturbing to the building community than a simple set of incontestable rules that all departments enforce consistently.

The interpretation of the efficient kitchen lighting requirement could be simplified that "General Lighting" in the kitchen is interpreted to be a majority of connected lighting load. This requires no change in standards language, and can be implemented immediately. Thus, fluorescent lighting would be interpreted to constitute 51% or more of the lighting wattage provided in kitchens. This is easy for inspectors to understand, confirm and enforce. They simply count up the maximum wattage allowed for each fixture, and verify that more of the watts are provided by dedicated fluorescent sources than incandescent sources. This approach also provides a modest check on "incandescent lamp creep," so that builders cannot install unlimited incandescent wattage.

This same logic could be applied to the bathroom requirement. However, given the status of the bathroom provision, simply reaffirming a commitment to the present, simple standards language would be a positive step.

Allowing substitutions, or "in lieu of" provisions, would greatly complicate compliance procedures, and would send confusing signals to the market for these fixtures. Rather than consider taking a step back, we recommend that the Commission stay the course, confident that with recent improvements in lighting technology and the fixture market the bathroom lighting provision will soon cease to be controversial.

3.1.3 Recommendation: Adopt Outdoor Lighting Standards

Outdoor lighting is a strong candidate for including the lighting provisions of Title 24. Basing code provisions on EPA's Energy Star specifications for outdoor fixtures would provide a coordinated national approach, which would be mutually reinforcing.

3.1.4 Recommendation: Consider Efficiency Standards for NEC Required Fixtures

The Commission should consider the potential for using the National Electric Code definition of required fixtures for inclusion in the lighting provisions of Title 24. Such a measure should be identified for future implementation if economic or market conditions change so as to make it cost effective.

3.2 Promote Commercialization of CFL Technology

3.2.1 Background

Compact florescent lamps (CFLs) have presented a very promising technology for over a decade. In that time, the variety of compact fluorescent lamp and ballast options on the market has mushroomed, and fixtures which are designed specifically to use CFLs have become available.

Fixture manufacturers across the country report that a preponderance of their fixtures designed to use CFLs are sold in California. California utility companies have promoted the use of screw based CFLs in both commercial buildings and residences with rebates and discount coupons. They have even given away millions of CFLs for installation in low income homes.

However, the penetration of CFLs still remains trivial in comparison to other lighting technologies. In 1992-4, CFLs represented 0.1% of commercial indoor lighting energy use statewide and 0.4% of residential lighting energy use. While there were an estimated 4.8 million CFLs installed in California residences at that time, only 20% of homes had any. Those who did, averaged two CFLs per home. Utilization of the technology has undoubtedly increased since then, but remains far below its potential.

There are a number of significant market barriers that are preventing CFLs from achieving their market potential. These can be addressed in two general categories: negative consumer attitudes, and the need for standardization.

Screw Based vs. Pin Based CFLs

There are two basic types of CFLs, screw based and pin based. It is important to keep the differences between these two types in mind when evaluating the effect of various market barriers.

Screw based CFLs come in a number of configurations and sizes, but all use the same medium based screw-in socket of standard incandescent A-lamps. They also all have an integral ballast, either magnetic or electronic, which is part of the lamp. The ballast in these integral lamps is a more expensive component than the glass bulb, but is limited by the shorter life span of the phosphors in the bulb. Because the ballast must be discarded with the bulb, there is pressure to keep the ballast as low cost as possible, which has often resulted in manufacturers using poorly performing magnetic ballasts.

The screw based CFLs are designed to be retrofitted directly into fixtures designed for incandescent lamps. Consumer convenience from this ease of retrofit is seen to be one of their primary assets. Because they come in a variety of sizes and shapes, they do not, however, always fit into the fixture. And,

importantly, these CFLs do not have the same photometric properties as incandescent lamps they replace, and so the light output patterns of the fixtures inevitably changes when a CFL is substituted for an incandescent.

Pin based CFLs, on the other hand, are comprised of only the glass lamp portion of the fluorescent system. A highly specialized pin-based socket connects the disposable glass lamp component to a ballast which is typically permanently mounted to the fixture. The configuration of the pin based socket is designed to insure that mismatches of lamp and ballast characteristics cannot occur. For example, pin based sockets change in configuration between magnetic and electronic ballasts, and by wattage rating of the lamp.

Pin based CFLs, thus, do not have the universal retrofit convenience of the screw based CFLs, but they do have other significant advantages. The disposable pin-based lamp can be significantly less expensive than the screw-in CFL with its integral ballast. The more expensive ballast is a part of the fixture, and so the cost of a higher quality ballast is more easily justified. Furthermore, since the fixture is specifically designed to receive a particular size and configuration of CFL (and limited to receiving only that lamp by it's pin-based socket), the photometric distribution of light from the fixture is more likely to be optimized.

Consumer Attitudes

The term "fluorescent" has powerful negative connotations for most consumers, based on their past experience of fluorescent lighting in offices and utility spaces. Many have also had unsatisfactory experience with early CFL products. People have long memories for unpleasant experiences. Presented with a product that they associate with unacceptable properties--hum, flicker, poor color rendition, unpleasant light quality, insufficient light output, early failure—they are resistant to reevaluating their assessment.

Lighting retailers who were asked by our study if customers had any complaints about CFL fixtures most often cited low light output, poor color, hum and flicker as the primary complaints. However, none of these problems are inherent in the technology any more. More advanced CFL technology has solved all of these problems. Other desirable features such as instant on and dimming are also becoming available.

This is news for consumers, and most retailers, who have yet to see these products reach the consumer market. Information about the positive new features of CFLs is not widely available to the residential consumer. Compact fluorescent lamps have yet to be advertised as a consumer product in the mass media. While the three major lamp companies do engage in competitive advertising to commercial customers, they have rarely used consumer based

advertising for promotion of efficient lighting products in homes. Instead, competition for market share among the lamp companies seems to be based more on competition for the loyalty of retail distribution outlets, rather than directly reaching out to the consumer about the merits of a particular product.

Utility companies have been providing the primary path for public education about CFL lighting, with brochures and demonstration centers, but their reach has been limited and their focus has been on energy savings rather than consumer attitudes. While energy efficiency may be a social good, it is not generally the prime criterion by which people choose their lighting. Lighting has many other aspects which are more prominent—pleasant ambiance, aesthetics, sparkle, safety, security, ease of replacement, etc. CFL lighting must succeed on many levels if we are to see its energy benefits adopted in the residential sector.

Utility programs have offered give-away, direct install and rebate coupon programs, all meant to get a few demonstration screw-based CFLs into people's homes to increase acceptance of the technology. Many of the CFLs distributed as part of the utility programs were lower quality lamps with poor performance characteristics, since there was an effort to keep the unit price low . Some of these "demonstration" lamps may have only reinforced negative attitudes. While millions of CFLs have been distributed and installed, and are out there saving energy, it is not clear that consumer acceptance has significantly improved.

How Many Consumers Does It Take to Change a Light Bulb?

Consumers are often faced with a insurmountable challenge in simply trying to replace a compact fluorescent lamp. Selecting the right lumen output and light color options and matching the base configuration, lamp configuration, and lamp wattage with the fixture shape or ballast capabilities requires an advanced knowledge of technical lighting terminology, if not a Master's degree in lamp procurement. Given the variety of options available, it is not very likely that the local hardware or office supply store will carry the right product. It is almost certain that the local grocery store, where turn-over is the name of the game, will not stock it. A specialty CFL will only take up shelf space while waiting for just the right customer, who then won't need another one for years. Instead, grocery stores can use the same shelf space to stock standard incandescent A-lamps as commodity items that work in 90% of all home lighting fixtures, and that are purchased multiple times per year. If a consumer must spend half of his or her Saturday driving around looking for the right replacement lamp, or must place a special order and wait for that certain configuration of CFL which fits their particular application, they are more likely to just give up and go back to an incandescent bulb.

Residential consumers are not the only ones who suffer from the excessive variability of CFL products. Institutional facility managers have found themselves faced with managing a supply of 20 or 30 different lamp types in order to keep the lights on in their buildings. Retail and wholesale outlets have found it prohibitive to stock a complete line of replacement lamps or ballasts. Lighting specifiers cannot get competitive bids because not enough products are "equivalent." With so many new products coming on line, fixture manufacturers cannot develop a line of fixtures that will achieve a stable market share and long term profitability. All of this is very time consuming and inefficient, and raises the cost of using CFLs.

Thus, we believe, that until there is more standardization of the product, compact fluorescents will not achieve widespread consumer acceptance, and will not realize the potential economies of scale available from mass production and mass marketing.

Industry Standards

Over the last decade, compact fluorescent lamps and ballasts have remained expensive, compromising their cost effectiveness. While options have multiplied and their performance characteristics have improved dramatically, sales of any one product have not proven a clear winner in the market place. Indeed, the pace of innovation has outpaced the capability of the lighting industry to adjust to the changes.

The structure of the lighting manufacturing industry in the United States may contribute to disruptions caused by this rate of innovation. There are now only three major lamp manufacturers, who compete intensely with each other to define their market share. All three operate on an international basis. There are a few dozen ballast manufacturers, some very large and established, and some very small and new. There are over 500 fixture manufacturers, who tend to be smaller businesses with a tightly defined market niche and geographic territory, and limited resources.

When a new product is announced by one of the lamp manufacturers, first the ballast manufacturers must respond by adapting their ballast technology to meet the operating requirements of the lamp. Screw-based CFL assemblers may try to market a new integral lamp/ballast combination. The dedicated CFL fixture manufacturers must respond by redesigning their fixtures to accommodate the new lamp configuration and light output pattern. Since ballasts are typically sold as part of a dedicated CFL fixture, the fixture manufactures must also procure a supply of ballasts that will function correctly with the new lamp.

Lamp manufactures often try to secure market share by making their lamp products as distinct as possible from the other manufacturers. They refer to them

by very different terminology. The lamps may have different operating characteristics or base configurations. Ballasts which are created to operate a new lamp are sometimes found later to be incompatible with another manufacturer's lamp which was believed to be equivalent. Given the constant rate of change and innovation, such incompatibilities sometimes are not discovered until a consumer goes to replace the original lamps.

One of the greatest concerns of the CFL fixture manufacturers interviewed was the cost of constantly re-engineering their fixtures to match new lamp technologies. Lamp-ballast incompatibility problems also caused them extensive field troubleshooting costs, raising their risks from using new lamps and generating considerable customer ill will. As a result, fixtures designed specifically for CFLs remain a premium item, with most products limited to high-end commercial applications.

In contrast, in Japan, the lighting industry is highly integrated. A single electronic firm often produces and markets lamps, ballasts, and fixtures. An innovation in one technology is systematically accommodated in the others to create a unified product for the market. Innovations in the industry have been accomplished quickly and smoothly. Perhaps as a result, CFL penetration is exceptionally high in Japan.

Industry integration, such as Japan's, is not the only solution to smoothing the introduction of new products in the lighting industry. Standards for products that are accepted by all manufacturers are also quite effective. The standard Edison screw-in base is an obvious example of a lighting industry standard that worked to reduce costs and increase market penetration by establishing a universal receptacle for incandescent lamps.

Other industries have also reduced the disruptive and costly impact of innovation, while maintaining competition, by adopting industry standards so that all manufacturers' products are compatible. The war of Beta vs. VHS video tape in the entertainment industry clearly held the market for back for years, and caused significant cost to the consumer. Once resolved, the videotape market grew rapidly. The computer industry is perhaps the best example of an industry that has managed to establish basic compatibility standards while still achieving both a dizzying rate of innovation and tremendous consumer acceptance.

Most industry standards of this type are developed by the affected industry members themselves. However, it is certainly possible to have government participation and encouragement. If there is a clear public good, government can push for industry standards, and take a leadership role in defining goals and facilitating the process.

In the recent past, the Department of Energy has used this convening function to bring industry groups together to resolve issues important to energy use. It has also coordinated and partially funded the many meetings necessary to develop standards. The National Fenestration Rating Council is an example of a voluntary industry group which, with DOE leadership and technical support, successfully developed and instituted a set of procedures and standards which are now an integral part of the window industry.

3.2.2 Recommendation: Support Public Service Advertising

The California Energy Commission should support public service advertising that helps educate consumers on efficient lighting options. Such a public service advertising effort would best be undertaken in support of other residential lighting efficiency policies, such as the adoption of appliance standards or expanded Title 24 standards discussed elsewhere in this report. Overcoming consumer resistance should be a balanced effort with a palette of other policies that promote or require efficient lighting.

Lighting efficiency and life cycle costs are not likely to ever be prime criteria for most consumers in their selection of lighting products. However, public service advertising can raise awareness of issues, and help to bring efficiency forward as a lighting selection criterion. Advertising could also focus on associated, non-energy features of CFLs, such as their long life or cool, safe operation, that may be more appealing to consumers.

The Commission could help form a statewide advertising consortium which would fund general advertising that would benefit all members of the industry, similar to the California Raisins or California Almond Growers advertising campaigns. For example, there are CFL ballast and fixture manufacturers whose primary market is in California, and who would benefit from a joint advertising effort.

The Commission could also initiate market research efforts that would identify key factors in changing consumers' resistance to compact fluorescent lighting so that any advertising could be targeted for maximum effect. For example, adopting a new industry wide name for CFLs that avoids the word "fluorescent" and instead creates a positive identification, might be a very powerful tool in overcoming consumer resistance.

It may be that other government organizations, such as Green Lights or the Energy Star program at US EPA could collaborate on consumer advertising. The EPA has been an innovator in using marketing methods to promote energy efficiency and transform market attitudes.

3.2.3 Recommendation: Support Industry Standards

The California Energy Commission should take a leadership role in helping to identify key areas in the lighting industry that could benefit from standardization, and in bringing diverse members of the industry together who can discuss the problems and suggest solutions. The Commission has already succeeded in assembling two lighting industry working groups, the ALPAC and LEAGue, who have made progress in identifying key issues that need resolution in order for the efficient lighting market to progress. Such a group could define a vision, and develop a set of objectives for lighting industry standards, the first steps towards resolution.

California can also strongly recommend that the federal government assist in promoting the development of standards. The actual development of industry standards must, however, be a national effort, lead by the lighting industry itself. There are many potential organizations who could take part or full responsibility for developing and maintaining standards. Manufacturing associations, or the industry professional association IESNA, might take the lead. Most likely, it will require a coalition of groups to develop the necessary consensus and broad overview necessary to develop a successful set of standards.

Industry standards that insure lamp-ballast compatibility and interchangeability of lamps will greatly assist the public and help achieve full market potential for compact fluorescent lamps.

3.3 Adopt Labeling Programs and Appliance Standards

3.3.1 Background

The consumer retail market is the most important arena for influencing residential lighting efficiency. The Commission is in a central position both to participate in "market pull" programs, based on labeling, and to institute "market push" programs, setting minimum standards for energy performance.

Many people argue that, if left alone, "the Market" will respond appropriately to consumer demands. This assumes that energy efficiency will become a consumer demand element. While consumers do benefit economically from the life cycle savings that result from efficient lighting fixtures, very few consumers have the long term perspective on economic choices that would take precedence over the shorter term motivations for selecting lighting, such as low initial price of the fixture, aesthetic choices, or convenience of replacing the lamp.

Few consumers also have a long term vested interest in the efficiency of their homes. Efficient lighting fixtures may be in place for twenty years or more, but households in California tend to move on the average of about every three years. Thus, most of the benefits for selecting efficient fixtures are likely to accrue to some future occupant. California homes are currently the most energy efficient in the nation, not because of economically rational consumer choices, but because of a comprehensive residential energy code that over the course of two decades has effectively raised standard construction practices in the state.

The indirect benefits from increased energy efficiency, in terms of conserved resources and reduced pollution, are diffuse, accruing to all the members of society, rather than the individual consumer. Thus, the promotion of energy efficiency is more appropriately a public policy issue than a consumer choice issue.

Market Strategies

It appears that the lamp companies are not yet interested in aggressively creating a market for their new CFL products. In CFLs, lamp companies have developed a product that is 3 to 4 times as efficient and lasts over ten times as long as their standard product. They have been hesitant to invest effort in marketing the new product, and have concentrated instead on product innovations so that they will be in the best possible position when a major market shift finally occurs. They appear to be waiting for some external catalyst that will force the market shift.

An "efficiency" labeling program, such as the Energy Star label described below, is a non-regulatory effort to influence conscientious consumers. Combined with

"market transformation" programs, similar to the utility DSM rebate efforts of the past few years, labeling is likely an effective way to help establish a new niche market. It is, however, unlikely to transform the niche market into the mass market, because that would require a more comprehensive influence on the millions of consumer choices which are made about lighting fixtures.

Appliance standards are the most fundamental way to raise minimum efficiency levels in a consumer market. In addition to energy efficiency, appliance standards can simultaneously address consumer safety. They allow the consumer to take a minimum level of performance for granted.

Manufacturers are very aware that regulations effect their market. Codes and standards have stronger impact than voluntary "market pull" programs because they are permanent and precise. All fixture manufactures interviewed for this study were knowledgeable about the impacts of Title 24 requirements on their business. While Title 24 was mentioned 22 times as a major influence on energy efficiency in lighting products, the Green Lights program was mentioned only once. Utility DSM programs were mentioned four times, always in the past tense. They were seen as a brief perturbation in the market, sometimes as a positive influence, but just as often as a negative influence.

Manufacturers rightly do not want to be subject to multiple, conflicting standards or frequent or erratic changes in the market. Stable, long term horizons allow manufacturers to plan for the future and make more secure investments. Appliance standards, especially those that are coordinated at a national level and phased in over a few year period, provide that stability for wise investments. Market based interventions, on the other hand, tend to come and go, as political will and fashionable policy styles shift. They may have a short term effect, but their long term impact may be to cause more confusion than clarity.

Labeling Programs

Labeling programs are an important means to provide consumers with sufficient information to be able to judge a product's performance. Without performance information, a consumer cannot compare between competing products or evaluate the most appropriate product for their use.

A national standard for labeling household lamps was recently instituted. Values for lumen output, wattage and life span now appear on all lamp packaging. Such a performance labeling program is a neutral first step in providing the consumer with more lighting information. The consumer is left to make his or her own assessment of the efficiency or cost effectiveness of the product.

A second level of labeling is to provide a ranking system based on an efficiency index. This ranking approach to labeling has been used with cars in miles per

gallon ratings (based on a wide range of assumptions) and for refrigerators, comparing performance and likely energy use. Europe is about to start doing this for household lamps, using a rating based on lumen output per watt. The European Commission is finalizing a mandatory procedure which is scheduled to start on a voluntary basis during the second half of 1997. The program requires lamp packaging to display an efficiency index from G for the lowest level to A for the highest.

A third level is a labeling program, such as the Energy Star label program developed at the EPA, which does not rank products, but rather provides a comprehensive specification which becomes an assurance of quality, both in terms of energy performance and other operating characteristics. Manufacturers are invited to submit products that meet the specifications, which approved, can then carry the label on their product packaging and advertising. The potential for marketing tie-ins with other programs that either promote or require labeled fixtures is a key feature of this approach

The EPA's first Energy Star labeling program for portable and outdoor fixtures was publicly announced in March 1997, with the first labeled fixtures expected to start appearing on retail shelves in the summer of 1997. A consortium of utilities in the northeast (the Northeast Energy Efficiency Partnership, or NEEP) has endorsed the process, and is planning to use the specification in their energy efficiency programs.

The Portable Fixture Market

Portable lighting in residences includes basically table lamps and floor lamps. These fixtures account for almost 23% of the installed watts and a little over 20% of residential lighting usage. They represent almost a quarter of all residential fixtures. Standard incandescent sources are responsible for over 90% of the wattage in these fixtures.

Portable lighting fixtures have very different market characteristics than those hardwired fixtures which are permanently attached to the house. They will never be affected by new construction standards. Considered a piece of furniture, rather than part of the operating equipment of a house, portable fixtures travel with the resident when it is time to move. Thus, residents frequently have a much longer term interest in their portable lighting fixtures than those which are hardwired to the walls or ceilings of their homes.

Portable fixtures are sold almost exclusively through retail outlets. An increasing number are sold at discount stores and national chain retailers, in a retail environment where there is no knowledgeable sales staff to provide information about product options. The market is very competitive, based on price and style. Imports account for 64% of all units sold.

With the advent of cheap imported table lamps and torchiers, which are currently being sold for prices as low as $9.99, the portable light fixture has almost become an impulse item at home improvement stores. Indeed, the unit sales of high wattage halogen torchier lamps has been skyrocketing in the last five years, reportedly increasing more than ten fold, while the average unit price has dropped more than two fold. Most of these are imported, and have much higher wattage than the table lamps and other floor lamp fixtures that they are clearly displacing in the market. It has been suggested that all of the energy savings which have accrued from the use of CFLs will be canceled by the increased use of torchiers. Our analysis suggests that, given this increasing population, within 15 years torchiers alone could add at additional 1,000 to 2,700 megawatts of installed load and consume an additional 700 to 1,900 gigawatthours of energy per year.

Dedicated CFL Portable Fixtures

There have been concerted efforts over the past ten years to persuade people to replace incandescent light bulbs in their portable fixtures with screw-in CFLs. Many utility programs gave away or rebated screw-in CFLs, instructing consumers to install them in the light fixture which they used the most—typically a large table lamp in the living room.

There have been a number of problems with this strategy of using screw-based CFLs to retrofit existing fixtures. First, energy savings may not persist, since it is so easy for anyone to replace the lamp with an other incandescent. Size variations have bedeviled selection of the appropriate CFL. Utility companies have been forced to sending out cardboard punch-out mock ups of CFLs, so consumers can see if a given CFL configuration will work in their fixture. Table lamps designed for incandescent bulbs do not provide the same light distribution patterns when fitted with a CFL, prompting complaints about the “light levels.” And finally, the magnetic ballasted CFLs often have annoying performance characteristics when switched frequently, and the inability to provide dimming or multi-level light output has limited their acceptance.

Given all of these limitations, many people have concluded that a better solution will be found in table and floor lamps designed specifically for CFLs, and which use a built in ballast, preferably an electronic ballast. They are often referred to as “dedicated fixtures.” The relatively expensive ballast component, with its longer life, stays with the fixture, while the lamp component can be replaced less expensively when needed. In the commercial market, dedicated compact fluorescent portable fixtures, such as office desk lamps, have been selling at prices similar to incandescent fixtures. The lower wattage and less heat produced have reduced insurance safety requirements , thereby lowering manufacturing costs.

The proposed Energy Star label for portable fixtures is meant to encourage production and marketing of such fixtures. It would apply to products that are hardwired to accept only a CFL or other efficient light source. The efficacy requirements start at 50 lumens per Watt (L/W) for fixtures using lamps at 20 Watts or less, and rise to 70 L/W for fixtures using lamps at 30 or more Watts. There are also requirements that larger fixtures include dimming or three-way switching capability, and a variety of performance standards to encourage the use of the most high quality and efficient components.

Other Residential Fixtures

Other residential fixtures are also appropriate for efforts to increase their efficiency levels. The context and arguments for more efficient outdoor lighting are presented above, in the section on Title 24 Standards. The EPA has developed an Energy Star specification for residential outdoor fixtures, which they will also roll out in 1997. We have recommended that Title 24 call for outdoor lighting fixtures meeting the Energy Star specification be required in all new homes. If such a policy makes sense for the new construction market, it will also eventually make sense for the general retail market.

A phased approach would first initiate the labeling program, and work to strengthen the market with consumer awareness campaigns and inducements for some residential market niches to utilize the products, such as mutli-family or institutional housing. Once the products are readily available, they would be required for new construction via the energy standards. Finally, as the market matures, an appliance standard would establish minimum levels of performance for outdoor fixtures. If such a standard were adopted for implementation at a future date, say three years hence, manufacturers would have a firm time horizon for adjusting their production capabilities and planning their marketing efforts.

Standards for other fixtures could eventually follow the same implementation path. The context for indoor hardwired fixtures is discussed above under the section on Title 24. There it is suggested that the National Electrical Code (NEC) requirements for lighting fixtures could be used to identify the set of fixtures appropriate to include in the standards. However, the NEC definitions would not work for appliance standards, because it is impossible to know where any fixture sold on the retail market will be installed. More likely, a standard for indoor hardwired fixtures would be based simply on size and efficacy.

3.3.2 Recommendation: Endorse Energy Star Labeling

The Commission should endorse the EPA's Energy Star residential lighting fixture labeling program, and actively look for ways to support the creation of a broader market for labeled fixtures.

Energy Star labeling will provide very clear opportunities for market transformation efforts, which may be led in the future either by the California utilities or by the Commission itself. It is unclear at this writing who will be responsible for leading market transformation efforts in the future, given the current state of flux in the field due to utility restructuring. However, it is clear that significant funding will be available for such efforts in the near future. Adopting the Energy Star labeling system will establish an important tool for those efforts, and importantly, will gain more impact by being coordinated with other efforts across the country.

The Commission should carefully review the specifications and insist that they address any issues specific to the California context. In addition, the Commission should participate in the development process to help to ensure that future versions of the program best aid California's needs.

3.3.3 Recommendation: Adopt Maximum Wattage Standards for Portable Lighting Fixtures

We recommend that the Commission adopt maximum wattage standards for portable lighting.

The appropriate level for such a standard should be carefully considered. Portable fixtures with very high wattage, such as 300 and 500 watt halogen torchiers, pose a serious burning hazard and fire danger in addition to consuming an inordinate amount of energy.

If wattage is capped at a certain level, pressure will be created for those more efficient fixtures which can maintain high light output at lower wattage, and this will be achieved without prescribing a given technology or design solution.

3.3.4 Recommendation: Consider Efficiency Standards for Other Lighting Fixtures

We recommend that the Commission consider implementing efficiency standards for lighting fixtures in the future, as part of its coordinated effort to establish energy efficient fixtures in the residential market.

The first fixture type to include for efficiency standards should be outdoor lighting fixtures, based on the EPA specifications for Energy Star outdoor fixtures. This measure would follow the earlier inclusion of the specification in the Title 24

standards for new construction, and would extend the requirement to the consumer market.

Eventually, based on the success of other aspects of the residential lighting program, the Commission should consider extending efficiency standards to higher wattage fixtures and/or those which are found to be operated for the longest hours. These could include portable lighting or hardwired fixtures for the home. It would be appropriate to base such standards on a nationally (or internationally) accepted specification, such as the Energy Star program, so that manufacturers are not subjected to unique state-by-state requirements.

4. SUPPORT LIGHTING EDUCATION

4.1 Lighting Education

4.1.1 Background

There is nearly universal agreement as to the need for better education on lighting energy efficiency, for all segments of the population which influence lighting use decisions. This need has been recognized by the LEAGue in its recommendations to the Commission, and earlier by the ALPAC. Lack of knowledge about efficient lighting strategies and products is seen as one of the primary barriers to their increased use. Education provides the means to increase knowledge and understanding, which is a necessary pre-condition to changes in practice and behavior.

The California Energy Commission is not fundamentally an educational institution. There is a large range of educational organizations that are already engaged in providing information to the groups that need to be reached with the lighting energy efficiency message. The problem is that few of these organizations include the topic of energy efficiency in their offerings. It may be mentioned in passing, in relation to a more primary topic, but this is rare.

There is a role for the Commission in focusing more educational emphasis and resources to the topic of lighting energy efficiency. This is a role not likely to be taken on by other organizations, because it is driven primarily by a desire to benefit the public interest. There are a multitude of smaller, individual interests, such as a manufacturer's desire to promote their energy efficient product, but these are too diffuse to generate the level of educational effort needed. The Commission, acting in the public good, can serve as a catalyst to draw out these individual interests and their resources, and to combine them into an effective statewide educational effort.

4.1.2 <u>Recommendation:</u> Continue the Three Tier Approach To Lighting Education

The Commission, starting with the ALPAC in 1988, began to catalyze the development of the Tier I, Tier II and Tier III lighting education programs, aimed at commercial lighting. The Tier I program was designed to teach building owners and managers about lighting efficiency options for their buildings. Tier II was an Associates degree program, offered through community colleges, for lighting practitioners. Tier III was a university-based professional design

program for training new lighting professionals. These programs have been in operation since the early 1990s. As a statewide strategy for lighting education, they provide a solid and workable foundation for reaching the three most important constituencies for lighting efficiency. They are in need of an update and a new shot of support to increase their effectiveness and reach.

Although there are university programs in other states that address lighting performance and efficiency, it is important to develop and maintain a high level of teaching expertise within the state, to train practitioners and to provide a continuing resource of information on the subject. Educational materials that emphasize the California context are also essential. Given the unique market conditions in California, and the size of the California economy, it is entirely appropriate to support California tailored curricula.

In addition, this educational framework should be expanded to include an education program for the residential lighting industry. There are currently some good textbook materials on residential lighting efficiency, but there is no organized effort of outreach. Audiences that need to be reached include home builders, electrical contractors, lighting retailers, and, of course, homeowners. For example, there was a very obvious lack of knowledge about efficient products among the lighting retailers who were interviewed for this study. As with the commercial lighting efficiency topic, there is no coherent and effective body of interest in promoting statewide education on residential lighting efficiency, other than a public goods agency such as the Commission. The Commission is uniquely situated to organize a residential lighting education program.

4.2 Skylighting and Daylighting

4.2.1 Background

The use of increased skylighting and daylighting, combined with automatic controls, has the potential to save significant energy, reduce peak demand, and enhance lighting quality dramatically. California's climate and the preponderance of single-story buildings make daylighting a natural energy efficiency strategy.

The use of daylight in California buildings to offset electric lighting could be much more common, but for a few outdated and misinformed attitudes on the part of decisionmakers which prevent its widespread application. Bad experiences from glass skylights installed in the 1950s are persistently recalled as a reason not to use the more advanced products available today. In addition, architects and engineers typically lack the knowledge and experience to implement successful daylit designs. Daylighting suffers not so much from being cross disciplinary,

than because it is not a core element of any professional discipline, and thus tends to be ignored by all. Education is the way to overcome these barriers.

Fortunately, California has an abundance of resources to help. Lawrence Berkeley National Laboratory is the site of DOE's national research center on daylighting. A number of premiere manufacturers of skylights and daylighting controls are located in the state. Utility programs (especially at Southern California Edison) have actively promoted daylighting projects, and have accumulated excellent experience which can be tapped.

4.2.2 Recommendation: Include Skylighting and Daylighting in the Three Tier Education Curricula

The Commission should take the lead in developing a statewide education and awareness program to encourage greater use of daylighting. This effort should catalyze the existing daylighting expertise, and should enlist the support of professional societies (AIA, IES, ASHRAE) and other groups who are influential with decisionmakers. In addition, there should be new daylighting curriculum modules developed for the Tier I, Tier II and Tier III education programs.

4.2.3 Recommendation: Develop and Disseminate Design Aides

A related effort in providing education on the use of skylights and daylight is to develop and disseminate simple design aides that will help building design professionals quickly generate successful daylit projects.

Architects and engineers typically do not have the time for careful optimization studies, such as have been available for custom buildings from the utility technical assistance programs. Very powerful computer design tools are available to assess daylighting conditions. However, these are too complex and time consuming for most designers to master or use. Designers must get it right the first time, and thus typically depend on past experience or accepted practice "rules of thumb" to make quick design decisions.

Designers would be greatly aided if they could refer to a set of simple design aides or rules of thumb, or a set of recommended "patterns" developed for typical building types and climate conditions in California. The Commission could collaborate with the professional societies, manufacturers and utilities in developing and disseminating such tools.

4.3 Certification

4.3.1 Background

The Commission has already invested its staff resources and credibility toward the creation of the NCQLP (National Certification of Qualified Lighting Professionals) organization. This effort is directed at establishing and maintaining a minimum standard of professional knowledge in lighting design, part of which includes lighting energy efficiency. It will not only reach new lighting people, but will also reach to those currently in practice.

4.3.2 Recommendation: Support NCQLP process

The Commission should continue to support Lighting Certification.

4.3.3 Recommendation: Request Certified Professionals on State RFQs

Certification of lighting professionals is meant to assure building owners that they will obtain a minimum level of knowledge and experience when they hire a lighting professional.

The State of California is a very large building owner, which would benefit from high quality lighting design services. Thus, it follows that the State of California should request that a certified lighting professional responsible for lighting design work on all state building projects.

5. SUPPORT RESEARCH ON LIGHTING ENERGY USE

Lighting energy use has been shown to have an enormous impact on statewide electricity use. Residential and commercial lighting together are believed to constitute 22% of statewide electricity use. Lighting has also been shown to have substantial potential for energy savings and demand reductions. However, until recently, little was understood about the statewide patterns of this energy use.

This is because statewide lighting energy use is not the product of large, centralized engineering decisions, but rather the interaction of human behavior with hardware, and of many, many small consumer decisions. This makes lighting energy use more amenable to study using statistical tools, looking at the behavior of a large sample of occupants and the characteristics of the lighting systems in representative samples of buildings.

This study was the first major effort to identify detailed patterns of lighting energy use in California. Using existing data collected by the utilities for other purposes, this project derived substantial information on baseline characteristics of residential and commercial lighting energy use circa 1992-94. The project also developed a methodology for analyzing the large available databases on building lighting characteristics, and constructed a computer model for assessing the statewide impacts of potential lighting policy options.

These products are a valuable resource, which if updated periodically, will continue to provide valuable insight into trends in lighting energy use and enable the Commission to more accurately assess the impact of efficiency programs. For example, The Commission has received the most recent utility Commercial End Use Survey (CEUS) data from around the state which could be used for an updated analysis of commercial lighting energy use. Using this data from all of the utilities would create a more representative picture of statewide use. (The current commercial analysis is based on data from the southern half of the state.) It is unclear, given utility restructuring, whether such building survey data will continue to be collected by the utilities. However, the Commission should make a provision that similar data be collected on a periodic basis to facilitate future assessments.

There is still some very useful information that could be extracted from the current datasets through additional analysis:

- Patterns of residential lighting energy use per square foot, rather than per household or per room.
- Variations in multi-family vs. single family, and low income vs. high income, patterns of residential lighting energy use.

- A comparison of the commercial data used in this study, which was assembled from three southern California utilities, to similar data from PG&E would improve the statewide validity of the commercial results. The PG&E data is less detailed, but could be compared on an aggregated level.

In attempting to create a comprehensive description of lighting energy use in the state, this project identified a number of areas where there was insufficient information available to be able to accurately describe the pattern or scope of lighting energy use, or to make informed decisions about appropriate policies. The following areas were identified:

- The impact of automatic controls on net lighting energy use.
- Non-energy impacts of efficient lighting which are of benefit to businesses and building owners.
- Patterns of lighting energy use for the Industrial Sector.
- Patterns of outdoor lighting energy use in commercial and residential buildings.

These research areas are discussed further below.

5.1 Document Impacts of Controls

5.1.1 Background

As discussed earlier in the section on commercial Title 24, it is generally believed that automatic controls should significantly reduce overall lighting energy use. It is clear that, in the right applications, they save significant energy. However, in reviewing the current literature, this study could find no conclusive proof one way or the other that controls reduced the net energy use of the building stock. Many field studies looking at “before and after” energy use with controls have shown a combination of both increased and decreased energy use within a building, or among a number of buildings. Those field studies have generally had very limited samples, and limited purposes determined by their private sponsors. There have been no comprehensive, carefully controlled studies to date which assess the overall impact of lighting controls. Thus, we do not have sufficient information to make any firm statements about the energy saving value of automatic controls.

The fundamental value of controls is in reducing the hours of operation of the controlled lights. This presumes that the occupants neglect to turn off unneeded lighting. In many cases, this is undoubtedly the case. It is not, however, universal There are also cases where a poorly calibrated control replaces manual switching by diligent occupants. In these cases, lighting usage can

actually increase as the result of the controls. While effects like this can be discussed on a case-by-case basis, they do not help to clarify the overall value of controls applied to a large population of buildings.

The Controls Market

Lighting control technology is a very quickly evolving field. There have been more innovative developments in lighting controls in the past decade then perhaps any other aspect of lighting industry. The miniaturization of electronics, innovations in sensing technology, and use of computer chips to provide "intelligence" have dramatically changed the potential of controls to respond accurately and appropriately to changing conditions. This field is directly benefiting from technological developments in other industries, and thus is likely to continue to evolve rapidly.

The primary market barriers to increased use of controls have been their complexity, resulting in labor intensive system design, installation and calibration, and the frustration of occupants at their inability to easily reprogram the controls, resulting in frequent disabling. Both of those areas are being addressed by the controls manufacturers. Simpler, user-friendly and system integrated controls are being developed, and these promise to help expand the market for lighting controls further.

Lighting controls are popular with building owners and facility managers who believe that controls achieve substantial energy savings for their facilities with relatively little disruption to the existing system. Retrofit controls are also usually considered cost effective in other areas of the country, precisely because those areas have less efficient lighting systems. As the market expands, the price of controls is also dropping, increasing their penetration into new areas, like residential lighting. Thus, it is believed that the market for lighting controls will continue to grow and mature, and that lighting controls will become increasingly common in the future in all building types.

Control Credits

Title 24 nonresidential lighting requirements have agreed with this positive assessment of lighting controls. The lighting control credits assume that the overall behavior of automatic controls results in a diversified reduction in operating watts, with a corresponding reduction in lighting energy use. For example, occupancy sensor control credits for private offices allow a 20% adjustment to the installed watts. When the lighting control credit values were set by the Commission, there was no good data on their overall effectiveness, so the values were set conservatively.

Despite all of this work and experience, the lighting industry has no way to confidently predict the energy impacts of controls for a generalized building, or a group of buildings. The primary need is for definitive field studies that measure the actual energy impact of controls over time and within a diverse building stock, and that can be generalized to a larger class of buildings.

5.1.2 Recommendation: Fund Field Studies on Lighting Control Performance

The CEC should fund studies that monitor the field performance of controls in representative groups of buildings, and so identify the overall energy impacts of controls. Studies should be performed for the commercial, industrial and residential sectors, and should consider both indoor and outdoor lighting.

These studies should help define statistically valid engineering values for energy use impacts for a variety of control types based on actual operating conditions in a variety of building and space types, accounting for user behavior, device aging and life expectancy, types of lighting system controlled and other relevant factors.

There are a number of reasons why California should pursue control studies that are specific to California buildings. The long standing Title 24 requirements for increased switching, such as for occupant accessible switches, daylight switched areas, and bi-level switching, has changed the nature of lighting circuitry in California relative to other areas of the country. Furthermore, the lighting control credits allowed under Title 24 should be validated and/or refined. The mild climate and greater availability of daylight influence the use of daylighting features and lighting approaches for unconditioned space. And the relative prevalence of controls in existing California buildings may influence results, by affecting user behavior or selection of lighting system types. Until such studies are completed, we can only make rough estimates of the actual impacts and value of lighting controls.

5.2 Document Associated Non-Energy Impacts

5.2.1 Background

The California Energy Commission has long been interested in promoting lighting energy efficiency. Efficient lighting saves energy for the consumer, reduces life cycle costs, reduces utility peak demand, and thereby results in significant environmental benefits. These are “public good” benefits to the state in terms of less pollution, and long term reduction in resource consumption.

However, there are other benefits to advanced lighting technologies and improved lighting design practices which are much more important to the owners and operators of buildings. Most of these benefits are undocumented, and so can only be discussed in anecdotal terms.

For example, the monetary value of productivity improvements due to improved lighting is vastly more important to a business owner than any potential energy savings. The cost of labor per square foot has variously been estimated from 100 to 400 times the cost of lighting electricity per square foot for American businesses. A mere 1% shift in productivity per square foot is potentially worth two to four times any potential lighting savings. Rumors of increased retail sales in daylit buildings have reportedly spawned a major change in the design approach of big box retailers. Many of the national chains have developed standard designs for their new stores that make extensive use of skylighting.

Similarly, reducing risks from natural disasters or accidents or vandalism or employee sickness can be a far more pressing concern to a business than long term energy savings. Daylighting can allow business to continue operations after natural disasters. Energy efficient strategies for outdoor lighting can reduce vandalism. Employee health benefits can be realized from electronic ballasts, which have less flicker and noise, reducing risks of lost time from headaches and stress, and even of lawsuits. Children in schools have better sustained performance under natural lighting conditions. All of these are suggested effects from energy efficient lighting strategies which could be documented with careful, statistically valid studies.

5.2.2 Recommendation: Initiate Studies of Non-Energy Impacts of Advanced Lighting Strategies.

The Commission should conduct the necessary statistical studies to provide authoritative information about these suggested benefits of advanced lighting systems.

This information has the potential to be vastly more influential as a force for market transformation than any other set of policies or regulations.

5.3 Track Trends in Lighting Energy Use

Reliable and useful information is the first step toward the creation of effective policies. Based on the findings of this project, the following areas of lighting energy use have been identified as in need of more information.

5.3.1 Recommendation: Investigate Industrial Lighting Energy Use

The Commission should initiate a project to collect and analyze data on industrial lighting energy use.

Our team made numerous attempts to collect data on industrial lighting in California, or at least sufficient information to make professional judgments on the characteristics and amounts of industrial lighting use. There is considerable case-by-case information about industrial lighting, but we could not locate any comprehensive data that would allow us to extrapolate any of this lower level information in order to make statewide estimates.

For example, we could find no source of industrial square footage for California. Apparently the CEC forecasting office has come to the same conclusion. The U.S. Census does not collect data on square footage of industrial businesses. Rather, it collects data on number of employees and value of yearly output. In 1979 the CEC made an attempt to correlate number of employees to industrial square footage. This resulted in values of industrial lighting energy use which followed cyclical employment cycles. Apparently, the methodology of deriving these numbers have not been revised or refined since.

The Lawrence Berkeley National Laboratory has been working on an national level study of HID lighting, which was not available as of the date of this report. This study should have some important information on industrial HID lighting. It will not, however, include other sources of industrial lighting, or California specific data.

Interactions between industrial lighting, lighting and building controls, daylighting, HVAC and on-site production are even less well understood.

5.3.2 Recommendation: Investigate Outdoor Lighting Energy Use Patterns

Outdoor Residential Monitored Data

The Commission should initiate a project to collect monitored data on residential outdoor lighting around the state.

This study reported detailed information on residential outdoor lighting energy use, based on self-reported data from the Edison Inventory. There is no monitored data available for residential outdoor lighting in California. Californians are suspected of having very different patterns of outdoor lighting use than other regions of the climate, due to our mild climate. These patterns may also vary within the state, by urban, suburban and rural area, or by climate or economic status.

Commercial Outdoor Lighting

The Commission should identify additional sources on outdoor lighting energy use, which may be available from utilities or other organizations, or else the Commission should initiate a project to collect, and then analyze the needed data.

The information on commercial outdoor lighting in the datasets used in this study was not available for all building sites, and was collected in varied formats, which prevented statistically valid comparisons.

The data that was available did suggest that commercial outdoor energy use is quite significant, and has potential for effective energy efficiency improvements. Analysis of the limited data found that the intensity of outdoor lighting installed wattage varied considerably between building types, from .05 Watts/SF and .60 Watts/SF (per square foot of indoor space). Thus, outdoor wattage could easily increase the overall lighting power density of a building by 30%. While much of this is produced by very efficient sources, there is also a considerable portion from low efficiency sources. Given the long hours of operation for outdoor lighting, it is clear that significant energy savings are possible.

There are currently no limits in California on outdoor lighting energy use. There are, however, restrictions on outdoor lighting in the ASHRAE/IESNA 90.1 lighting standards and in other states' energy codes. California may want to include such outdoor lighting measures in the commercial standards in the future. Before doing so, the Commission should have reliable information on commercial outdoor lighting use intensities, pattern of operation, lighting sources, operation of controls, and the purposes of such lighting (security, advertising, parking, decorative effects, etc.).

5.3.3 Recommendation: Update Residential and Commercial Baseline Information

The Commission should implement a policy to periodically collect data on the lighting characteristics of the existing statewide building stock, both residential and commercial.

In the past, such data has been collected by utilities for their own needs. The content and structure of the information varies between each utility territory, and is generally not available for public review or analysis. Given the uncertainty of the utility restructuring process, it is unclear whether any of this data will be collected or available in the future.

The analysis in this study is based on data collected between 1992 through 1994. More recent, comparable information is available. For example, The Commission has received the most recent utility Commercial End Use Survey

(CEUS) data from around the state, which could be used for an updated analysis of commercial lighting energy use. Using this data from all of the utilities would create a more representative picture of statewide use. (The current analysis is based on data from the southern half of the state.)

The baseline data is a valuable resource, which if up dated periodically, will continue to provide valuable insight into trends in lighting energy use and enable the Commission to more accurately assess the impact of programs.

5.3.4 Recommendation: Document Residential Lighting Power Densities

The data set used in the residential analysis for this study could be analyzed for watts per square feet of each room type. Such information would be very valuable in considering an alternative approach to regulating residential lighting.

Such an alternative approach, that would specify maximum installed watts per square foot for various room types, would bring the residential standards in alignment with the approach used in the commercial energy code. If a watts per square foot cap were placed on kitchen or bathroom lighting, more efficient fixtures would have major market advantage, allowing higher light levels within the standards. Such an approach would be technology neutral.

An important first step in considering this new approach is to understand the existing levels of illumination and lighting power densities in California homes.

5.3.5 Recommendation: Extend Use of the California Lighting Model

This project produced a computer model of residential and commercial lighting energy use in California. It takes the baseline lighting characteristics and operating patterns, and uses them to allow various energy efficiency policy options to be modeled over time.

This same tool can be used to monitor the impact of new trends, changes in existing lighting conditions per new data sources, or to assess the impact on statewide energy which could result from new innovative lighting technologies. The Commission should take advantage of this tool for future analysis.